Ikonos Pan-sharpened Products Evaluation

(Preliminary Results)

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Introduction

- **Objective**
  - Provide quantitative assessment of the radiometric and spectral fidelity of pan-sharpened products produced with Ikonos data
- **Impact**
  - Radiometric and spectral fidelity is needed for applications involving machine-based exploitation algorithms such as spectral unmixing
- **Options to NIMA**
  - In-house production by NIMA
  - Purchase Space Imaging (SI) pan-sharpened products
- This work supplements the evaluation of Ikonos under the Commercial and Civil Applications Project (CCAP)

Overview

- **Background**
- **Methodology**
- **Observations**
- **Application**
- **Conclusions**

Background

- Sensors on board Ikonos collects coincidental panchromatic and multispectral (MS) data/imagery at nominal GSDs of 1 and 4m respectively
- Ikonos MS data/imagery is a 4 band product with bands centered at 480.3 (blue), 550.7 (green), 664.8 (red), and 805nm (near infrared)
- Pan-sharpening fuses the lower spatial resolution MSI data set with the higher spatial resolution panchromatic data
- The result is a MSI product with an effective GSD approaching that of the higher spatial resolution pan image

Ikonos MS and Pan-sharpened Imagery

True Color Composites

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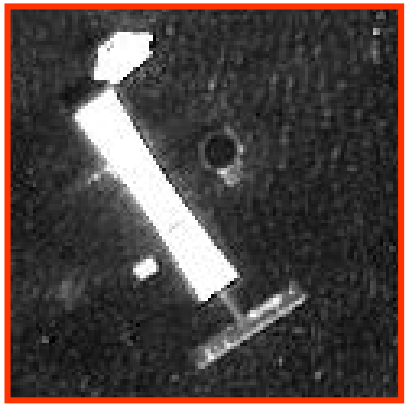
4m MSI (512x512)



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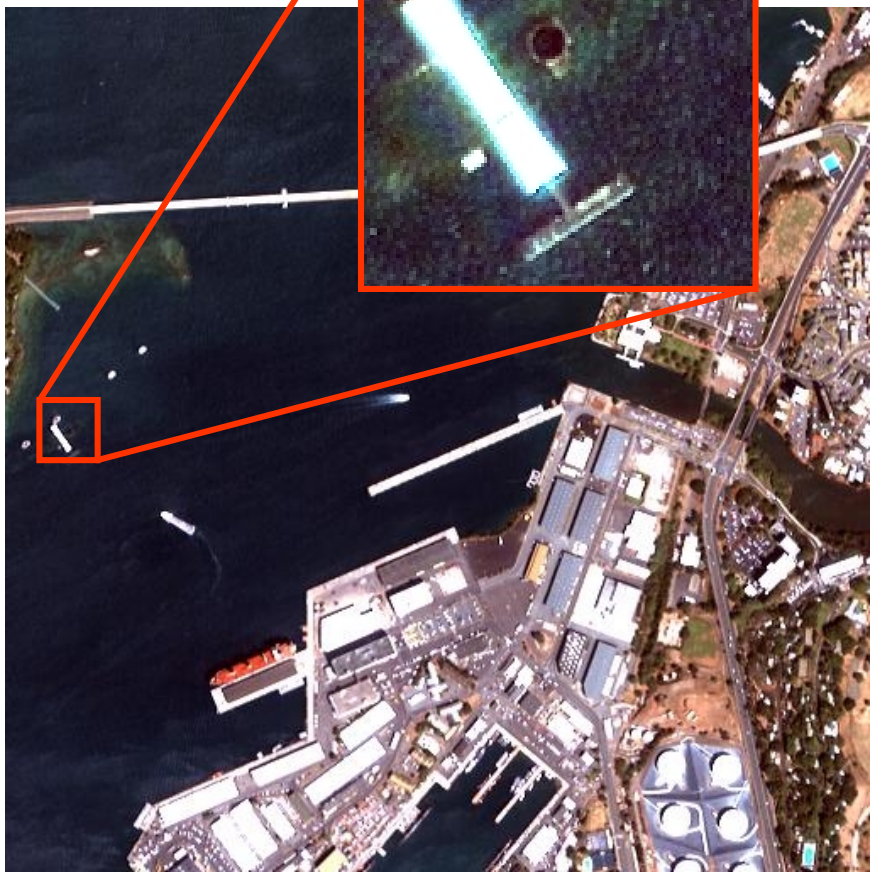
1m Pan (zoom)



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1m Pan-sharpened (2kx2k)

Ikonos MS and Pan-sharpened Imagery

True Color Composites

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4m MSI

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1m pan (zoom)

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1m pan-sharpened

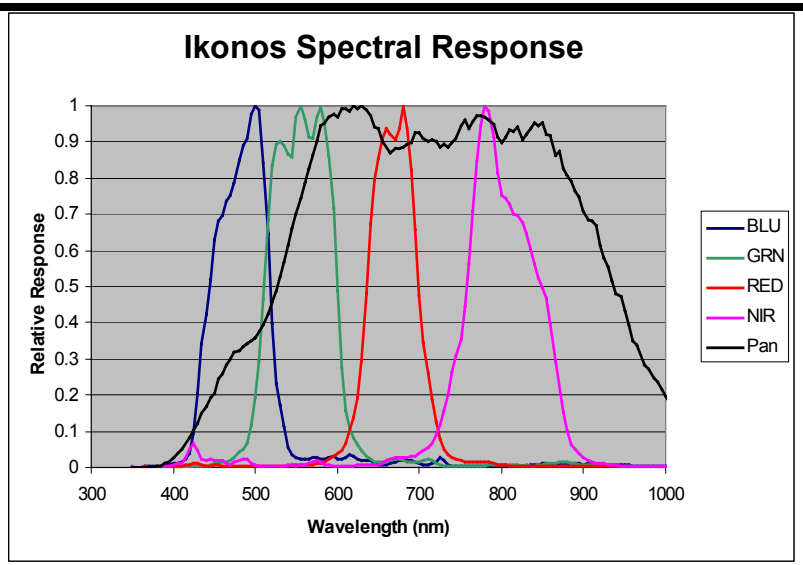
Pan-sharpened Products Assessed

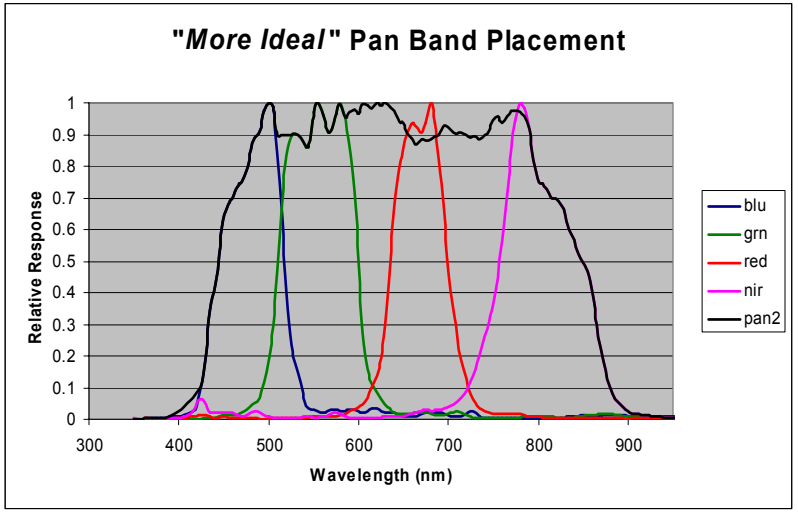
- **Space Imaging**
  - Pan-sharpened imagery purchased directly from Space Imaging
  - ***SI does not claim to maintain the radiometric and/or spectral fidelity in the pan-sharpened products***
  - Sharpening methodology/techniques/algorithm used by SI are unknown due to non-disclosure

- **NIMA**
  - Pan-sharpened imagery produced by NIMA using the SHARP algorithm
  - SHARP algorithm is designed to maintain spectral accuracy (with proper spectral band passes and overlap)
  - ***Due to the relative placement and shape of the spectral response functions between the Ikonos panchromatic and MS sensors, SHARP is not expected to perform optimally with Ikonos data***

SHARP with Ikonos Data

- Problems with SHARP and Ikonos data
  - The blue band mostly falls outside of the 3dB level of the pan band
  - The pan band response extends beyond the NIR
  - The green and blue bands overlap substantially
- Ideally the MSI bands should fall just within the spectral range of the panchromatic bands



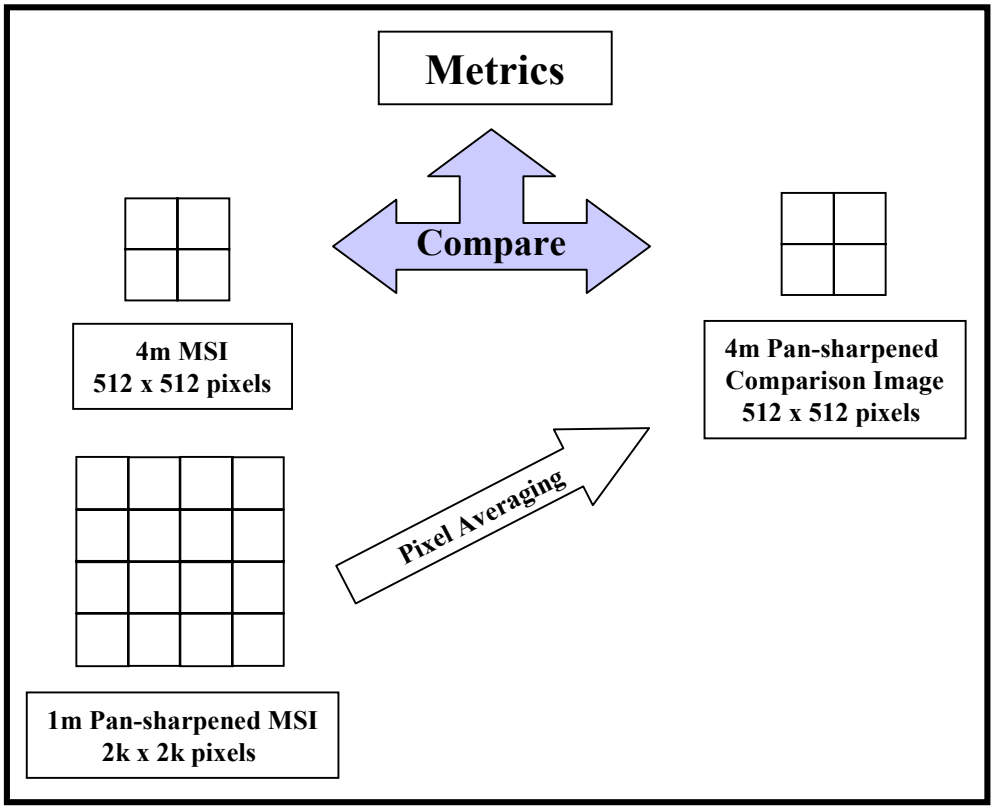


Methodology

- SI and NIMA pan-sharpened products were compared to the original Ikonos MSI products
- Criterion
  - Visual assessment
  - Histogram comparison
  - Comparison metrics
    - Bias and Gain
    - RMS pixel error
  - Spectral angle analysis
- Metrics were compared globally and locally
  - *Global* - entire statistics of single band image
  - *Local* - single pixel spectra

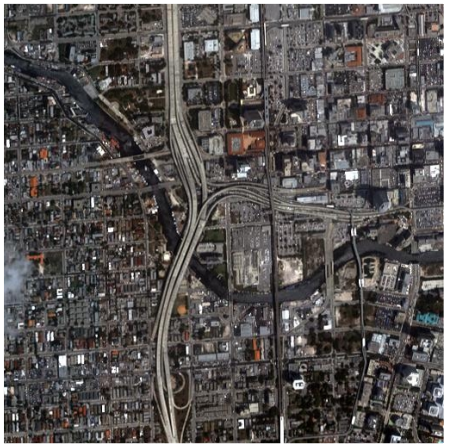
Processing and Metrics

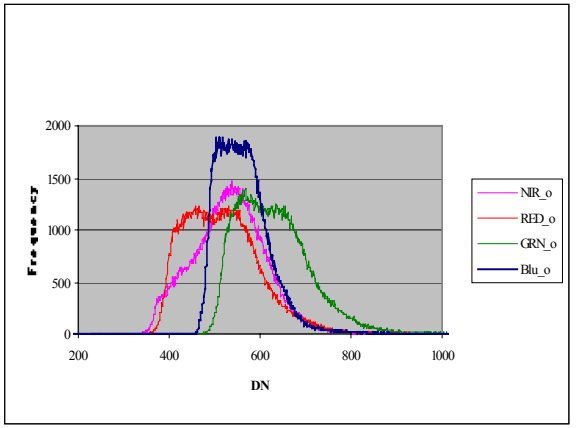
- Image Processing
  - Create common GSD format for comparison
  - Pan-sharpened products were by a factor of 4
- Comparison Metrics
  - RMS pixel error
  - Bias and Gain
  - Spectral angles



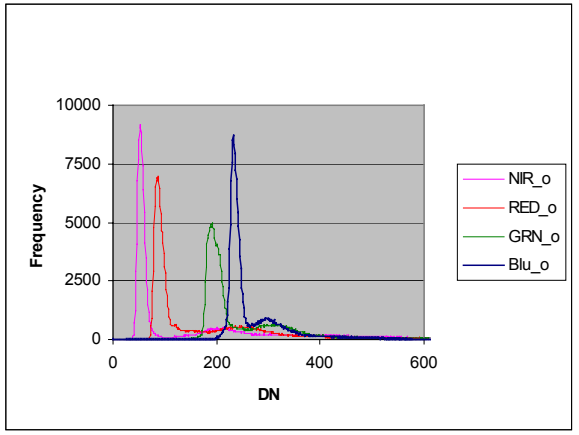
Test Imagery

- Results of pan-sharpening can vary based on scene content
- Image chip
  - MSI 512 x 512 pixels
  - Sharpened 2k x 2k pixels
  - 11 bit data
  - Radiometrically corrected only (no geo-rectification)
- Miami
  - Mostly urban and vegetation
- Pearl Harbor
  - High water content





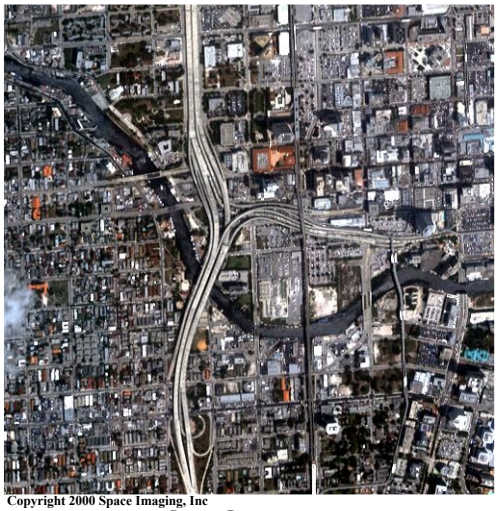
Miami



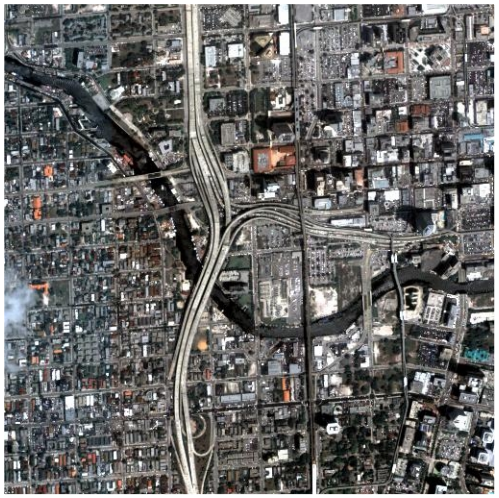
Pearl Harbor

Miami Data Set

SI



ORIGINAL



NIMA

Pearl Harbor Data Set

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SI

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ORIGINAL

NIMA

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Image Histograms

(Miami)

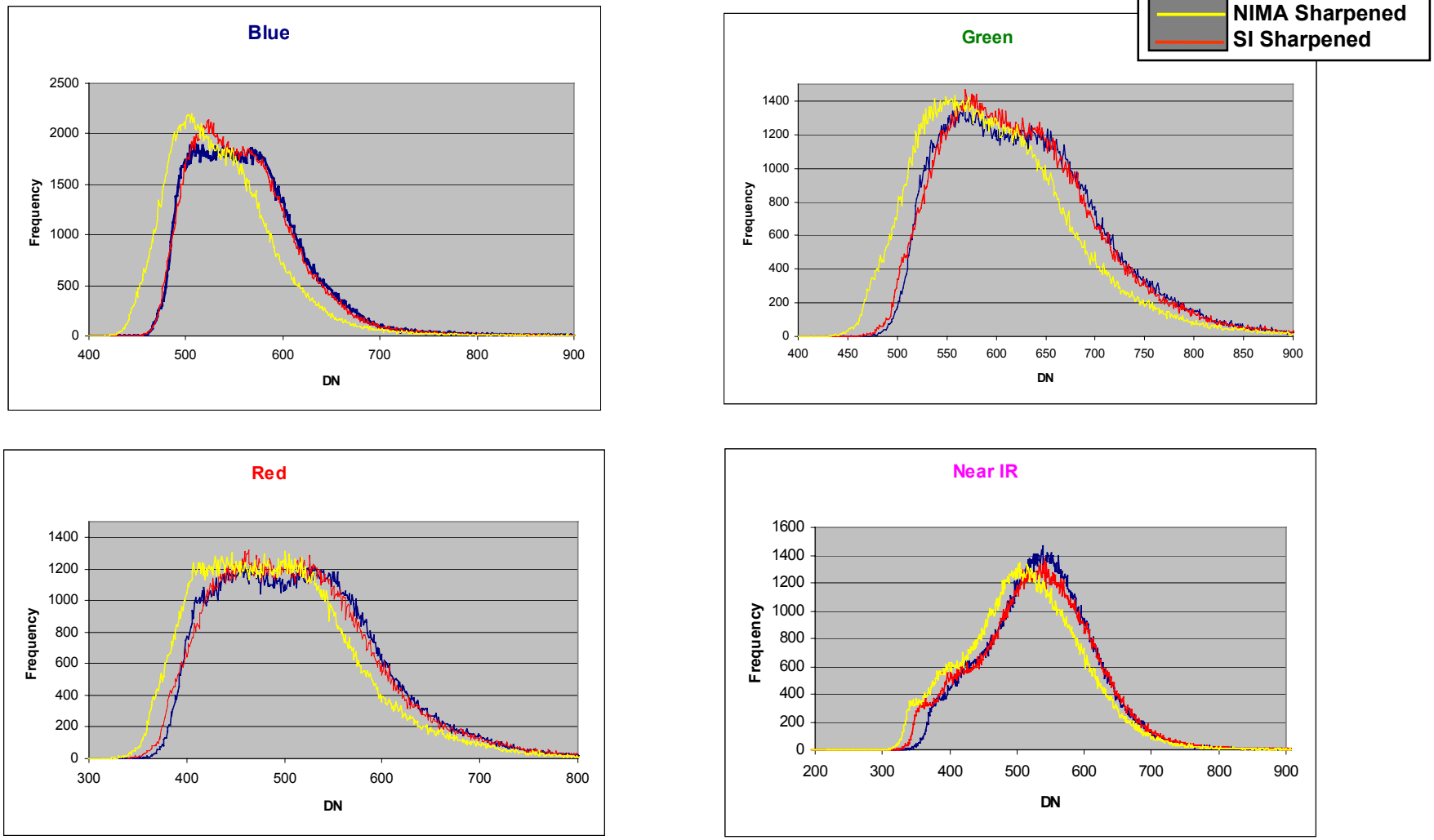
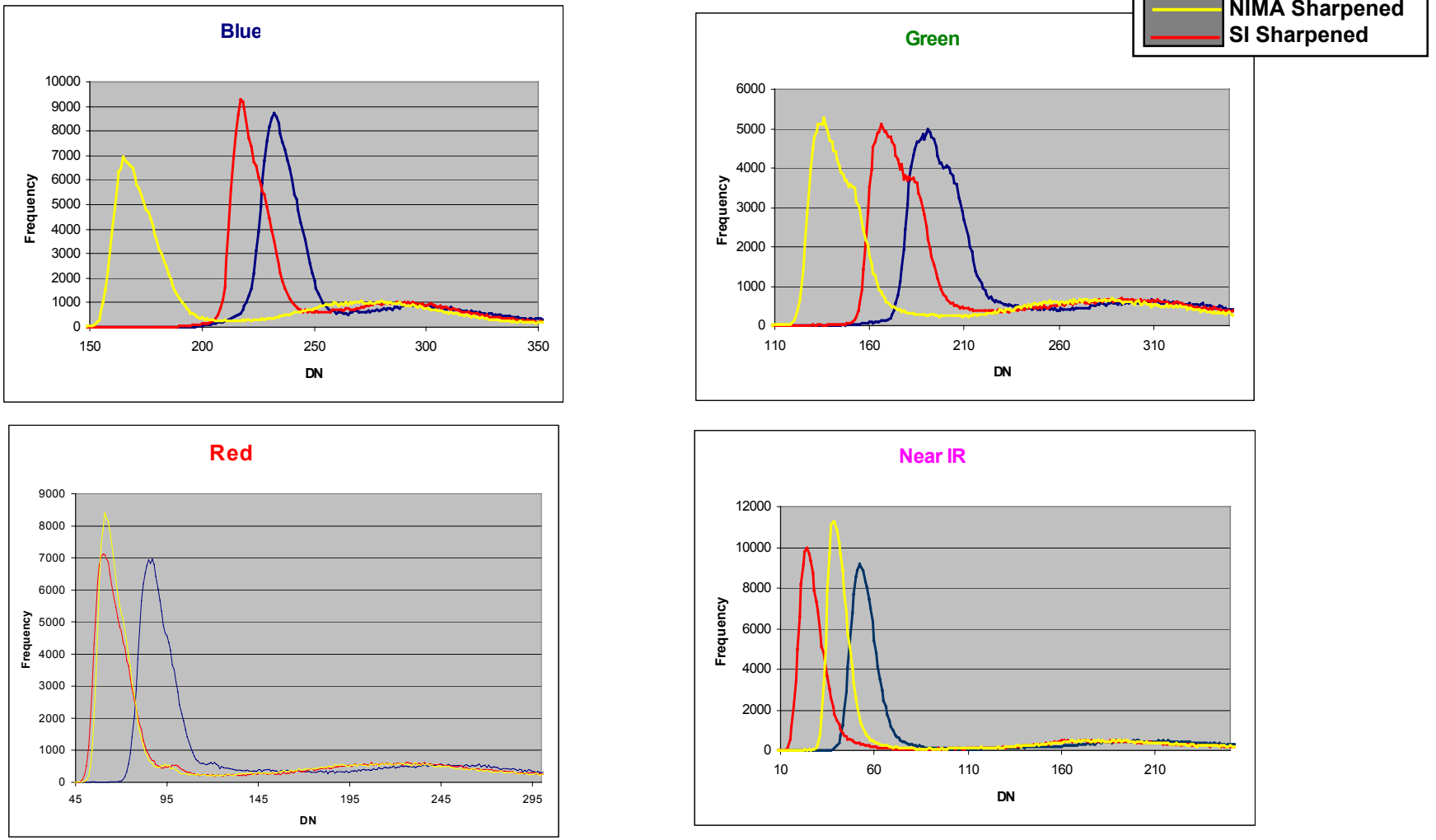
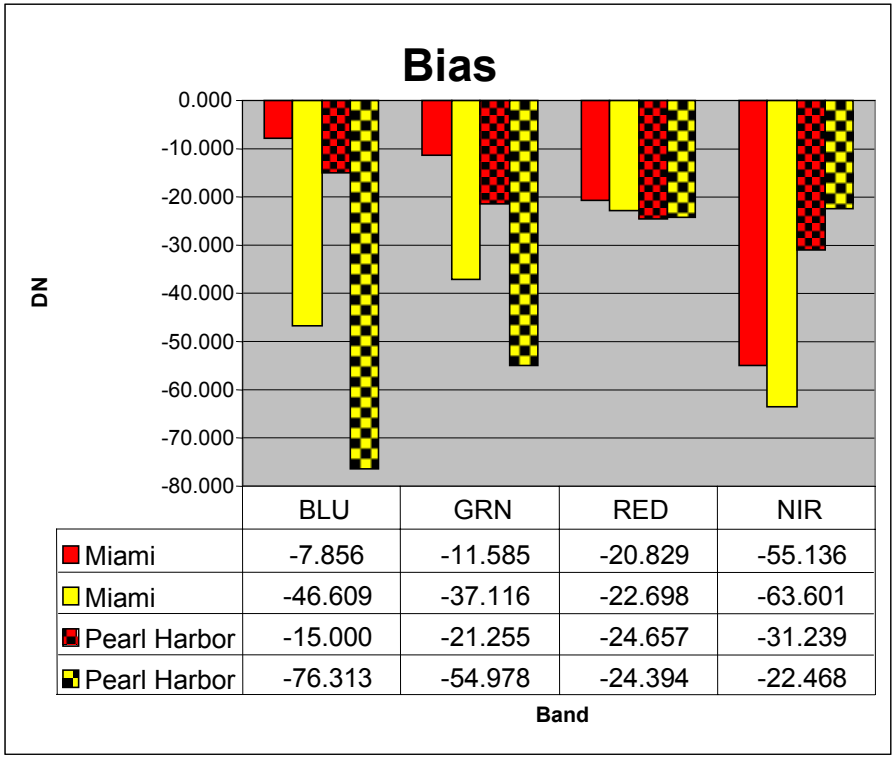


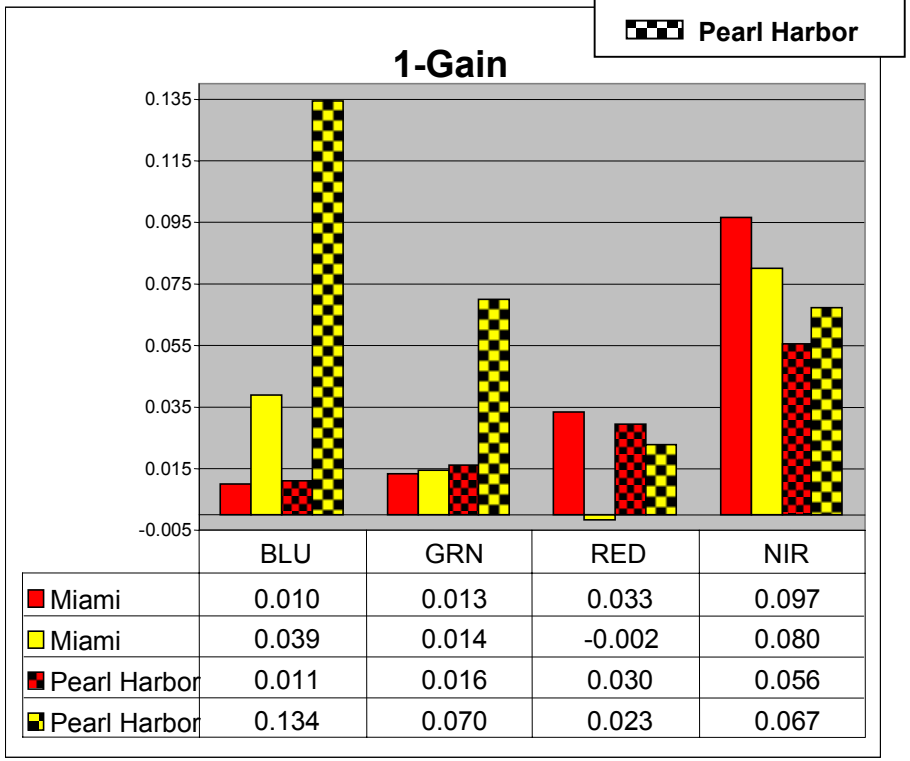
Image Histograms
(Pearl Harbor)



Bias and Gain

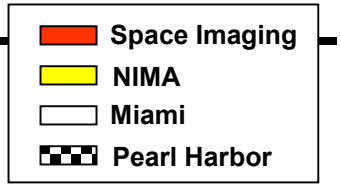


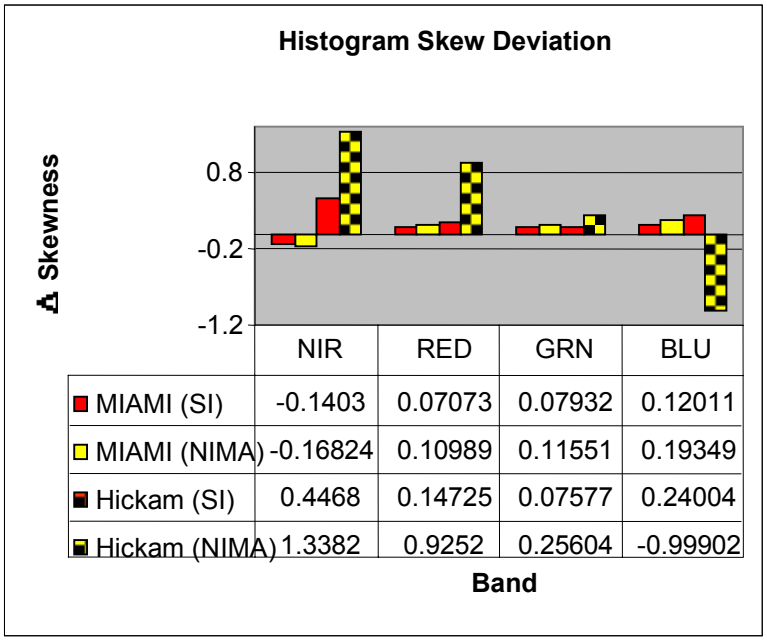
	BLU	GRN	RED	NIR
Miami	-7.856	-11.585	-20.829	-55.136
Miami	-46.609	-37.116	-22.698	-63.601
Pearl Harbor	-15.000	-21.255	-24.657	-31.239
Pearl Harbor	-76.313	-54.978	-24.394	-22.468

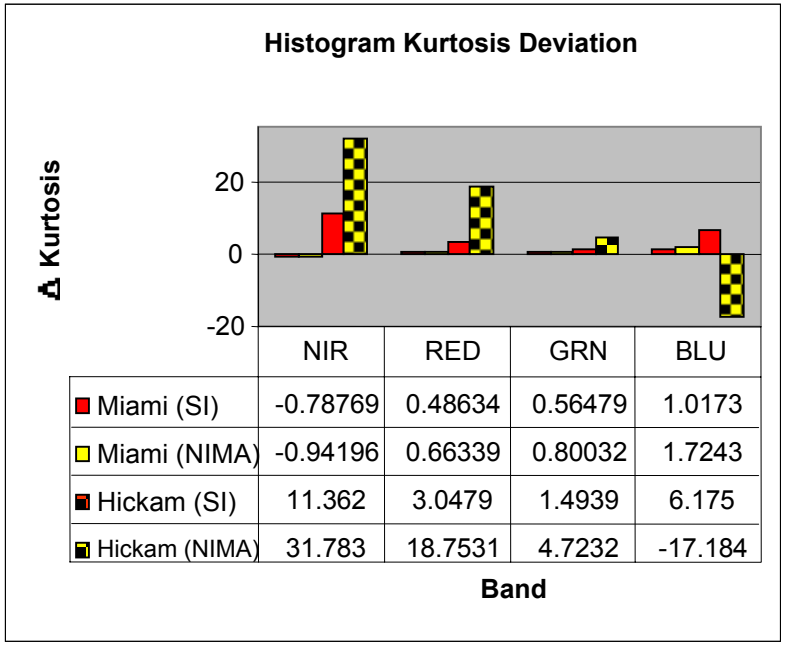


	BLU	GRN	RED	NIR
Miami	0.010	0.013	0.033	0.097
Miami	0.039	0.014	-0.002	0.080
Pearl Harbor	0.011	0.016	0.030	0.056
Pearl Harbor	0.134	0.070	0.023	0.067

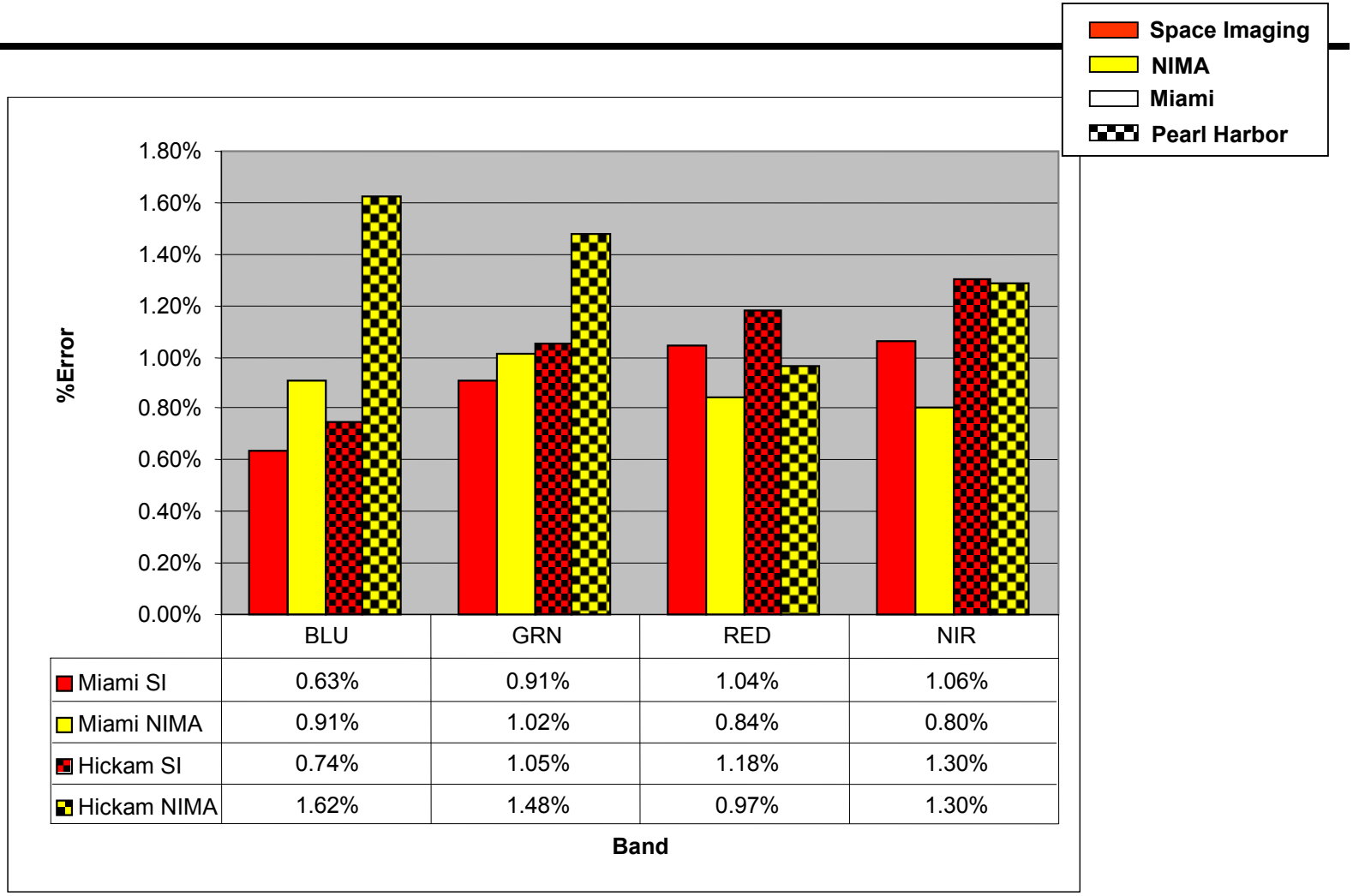
Skewness and Kurtosis







RMS Pixel Error

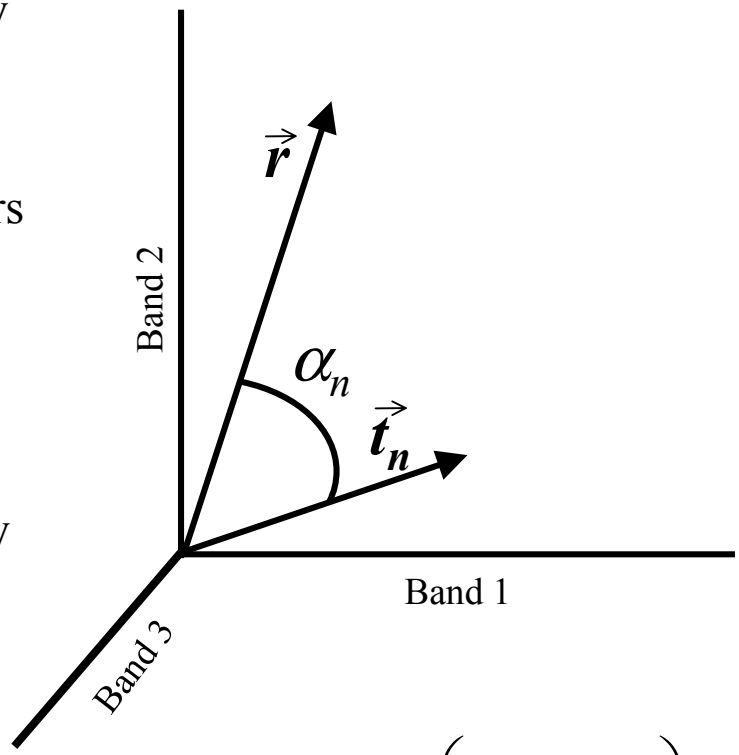


	BLU	GRN	RED	NIR
Miami SI	0.63%	0.91%	1.04%	1.06%
Miami NIMA	0.91%	1.02%	0.84%	0.80%
Hickam SI	0.74%	1.05%	1.18%	1.30%
Hickam NIMA	1.62%	1.48%	0.97%	1.30%

Spectral Angles

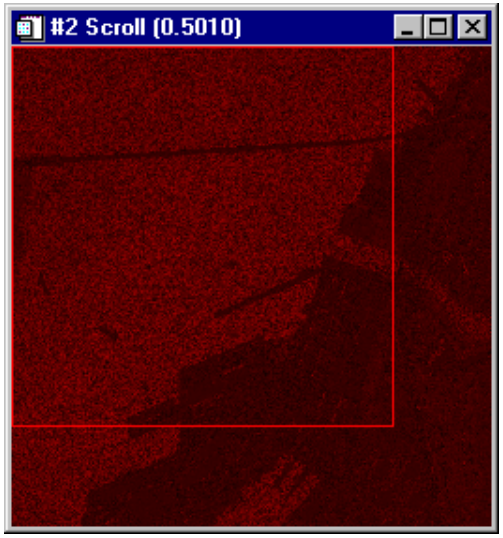
- The spectrum at the n^{th} pixel is represented by the 4 dimensional vector $\boldsymbol{t_n}$
- A reference spectrum is represented by $\boldsymbol{r}$
- The angular distances (α_n) between the vectors are computed for each image
- Spectral angular distance is insensitive biases introduced by the sharpening method
  - Color is represented by the angle
  - Intensity of illumination is represented by the magnitude
- Many machine-based algorithms rely on the spectral angle separation to achieve their objectives

3-D Analogy

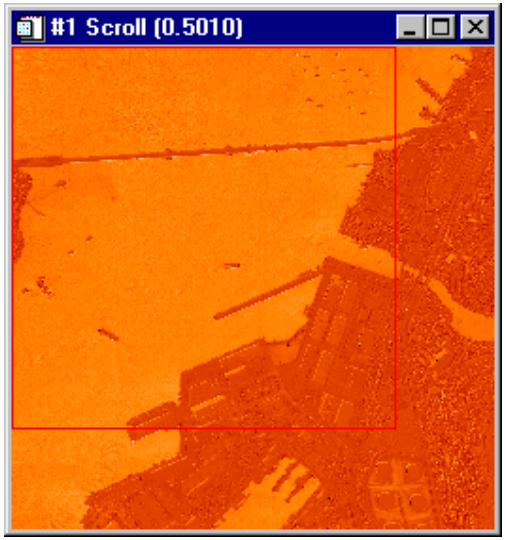


$$\alpha_n = \cos^{-1}\left(\frac{t_n \bullet r}{\|t_n\| \bullet \|r\|}\right)$$

Spectral Angle Analysis
(Global)



NIMA-Sharpened
Difference Rule Image

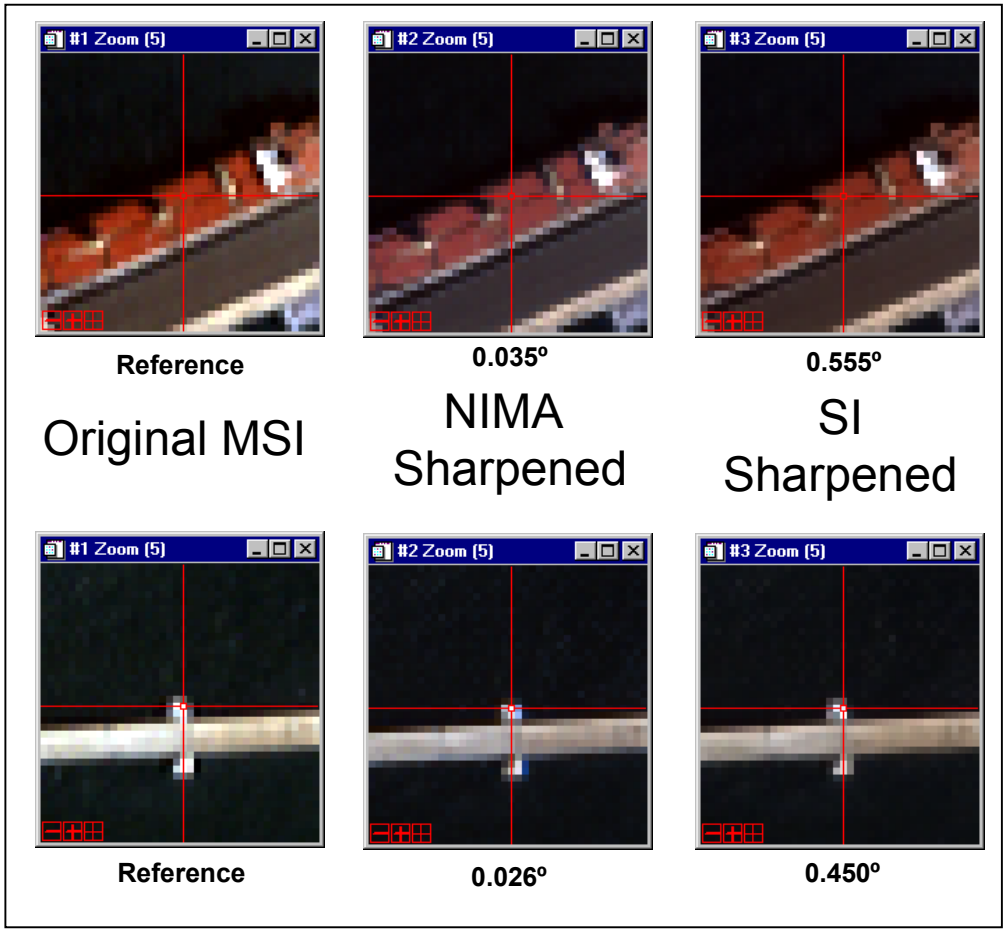


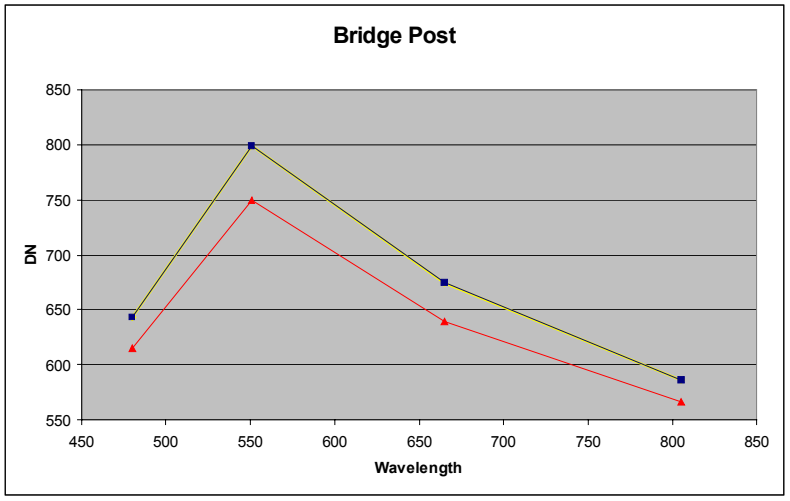
SI-Sharpened
Difference Rule Image

	MEAN (Degrees)	RMS Error
SI (Miami)	0.37	4.60
NIMA (Miami)	0.01	0.15
SI (Hickam)	3.98	42.49
NIMA (Hickam)	0.07	0.89

- Spectral angles were calculated between the pan-sharpened data and the original MSI
- NIMA products demonstrated a high level of spectra similarity based on small angles
- Although SI products demonstrated relatively low mean angular distances, the variance throughout the image was greater than the for the SI products as reflected by the RMS pixel errors
- Typical threshold used for image classifications based spectral angles is 0.057 degrees

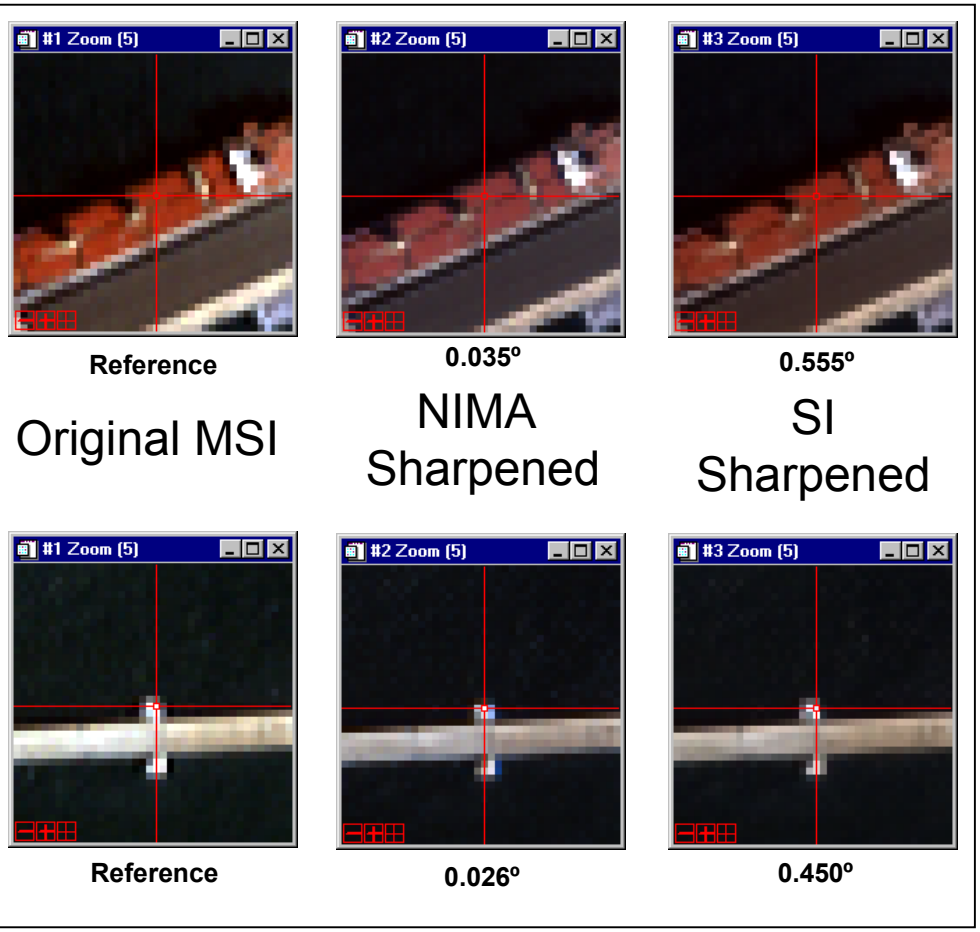
Localized Pixel Spectra

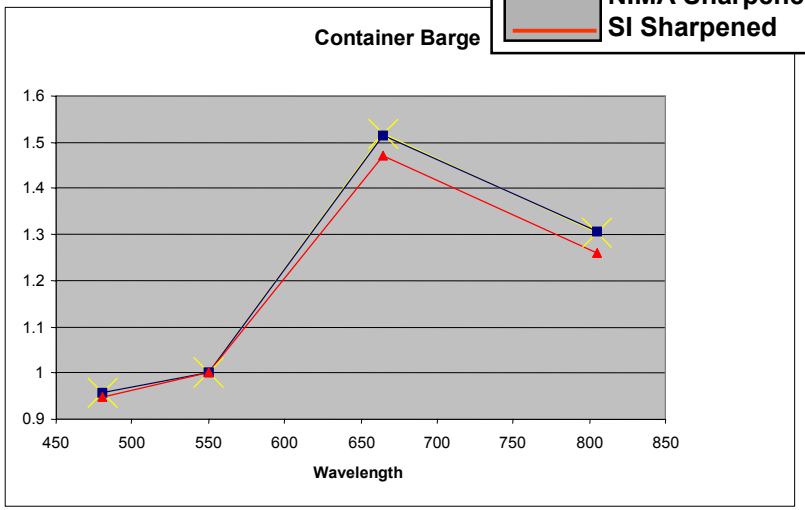


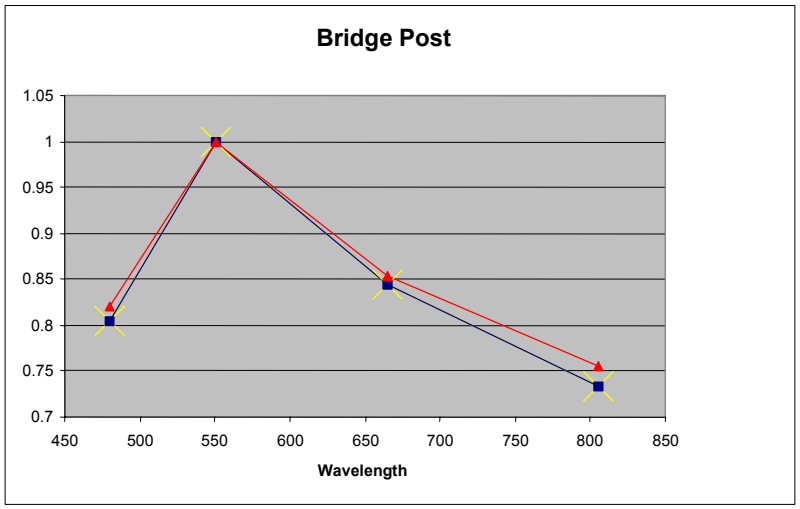


Localized Pixel Spectra

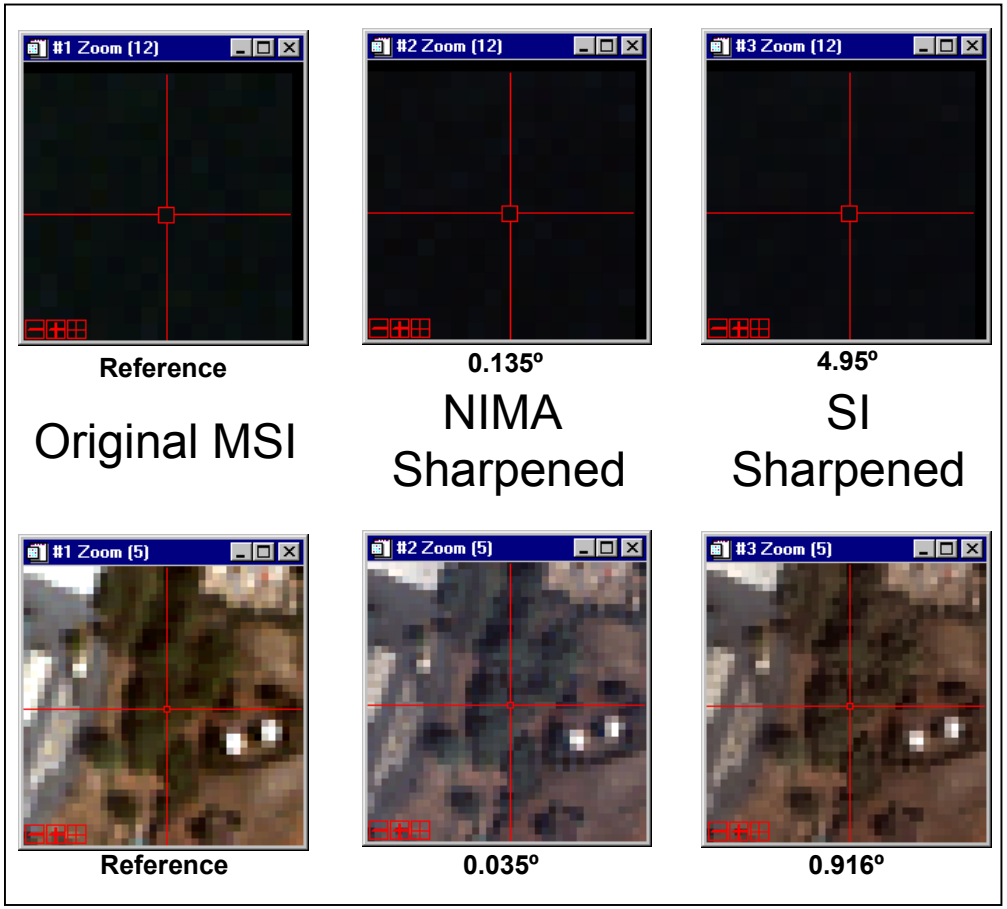
(Normalized)

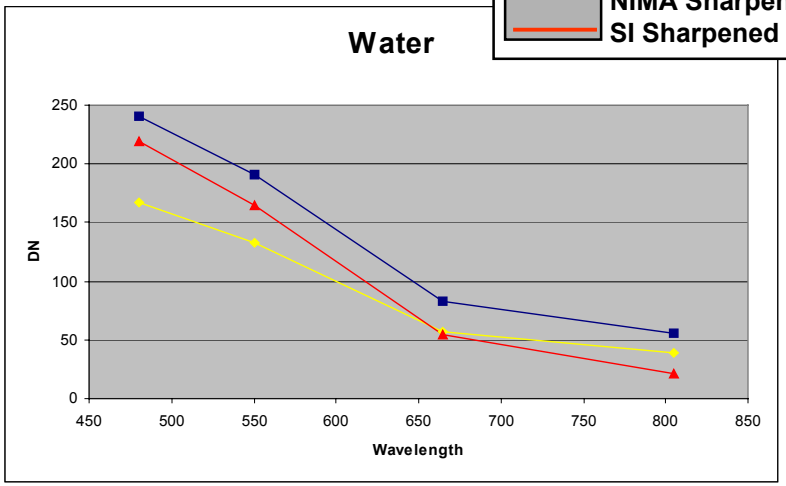


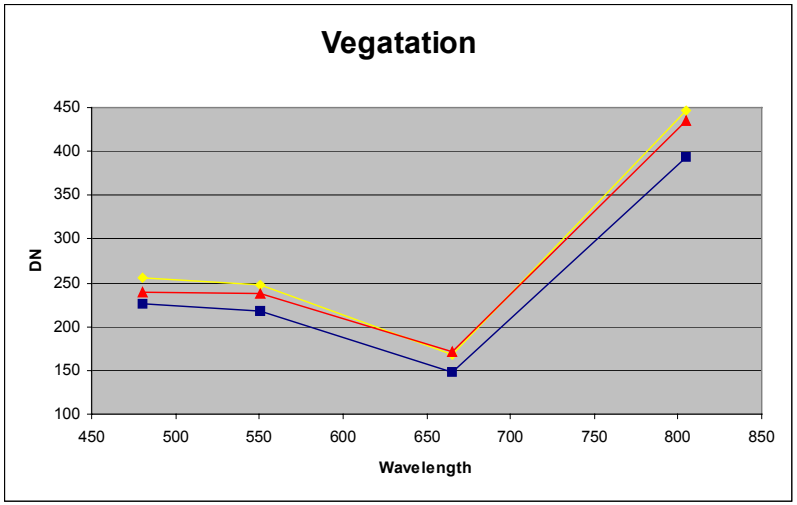




Localized Pixel Spectra

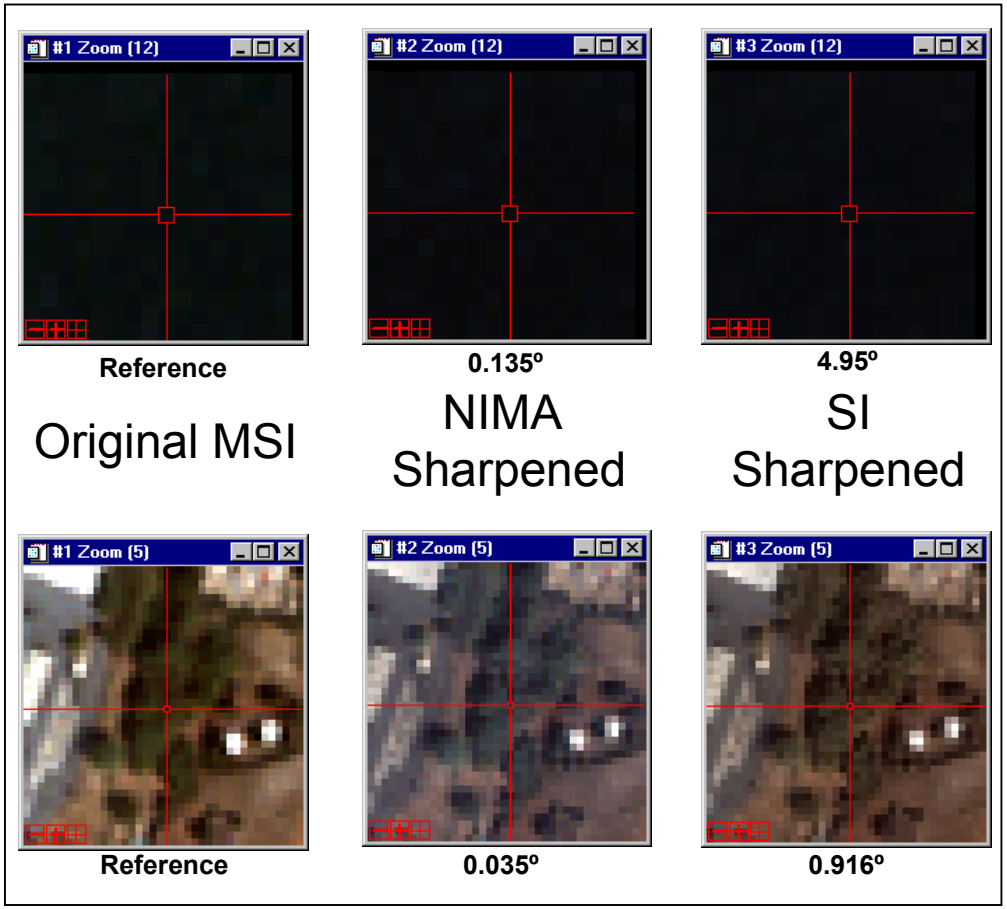


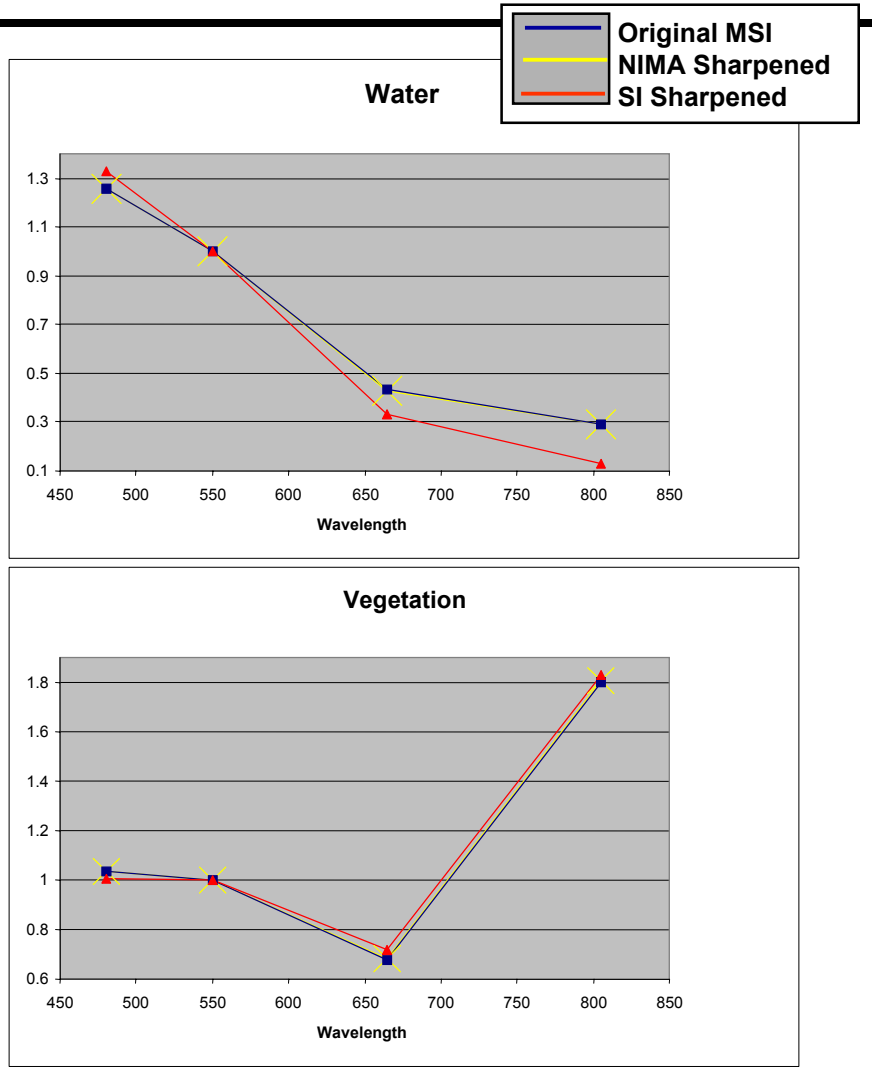




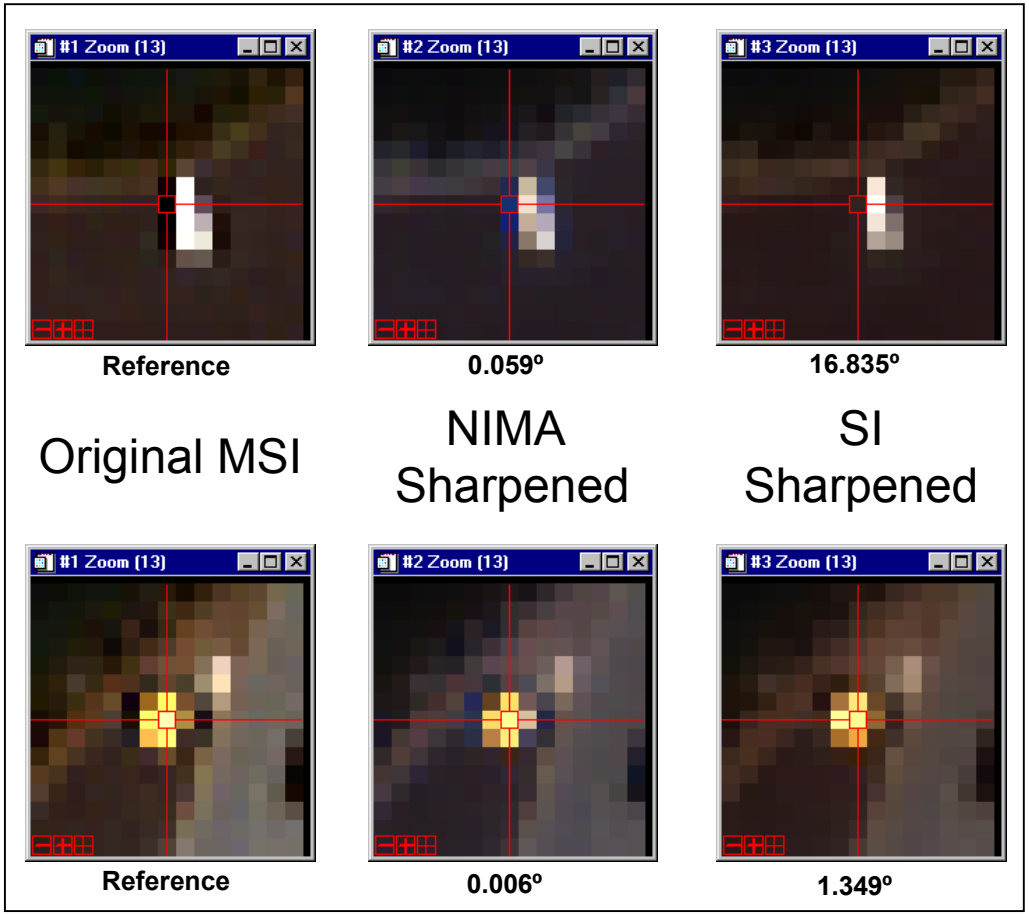
Localized Pixel Spectra

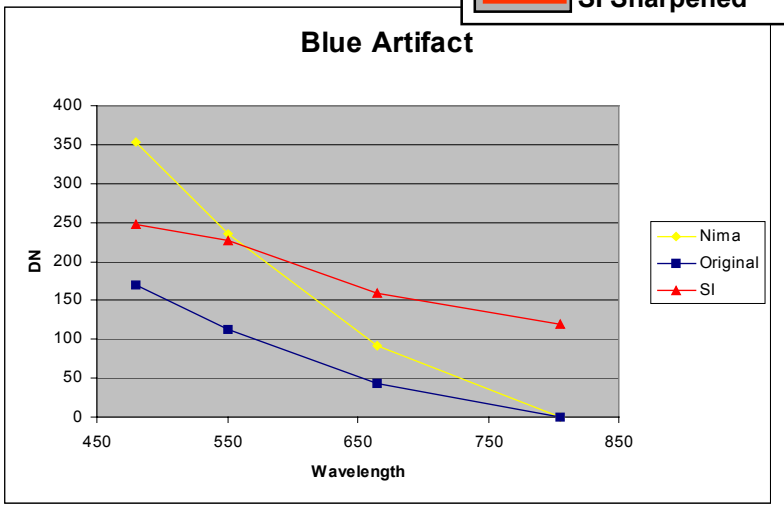
(Normalized)

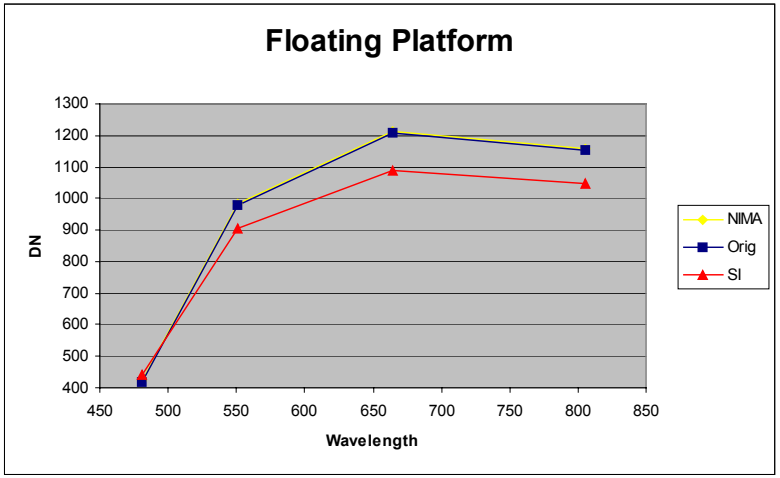




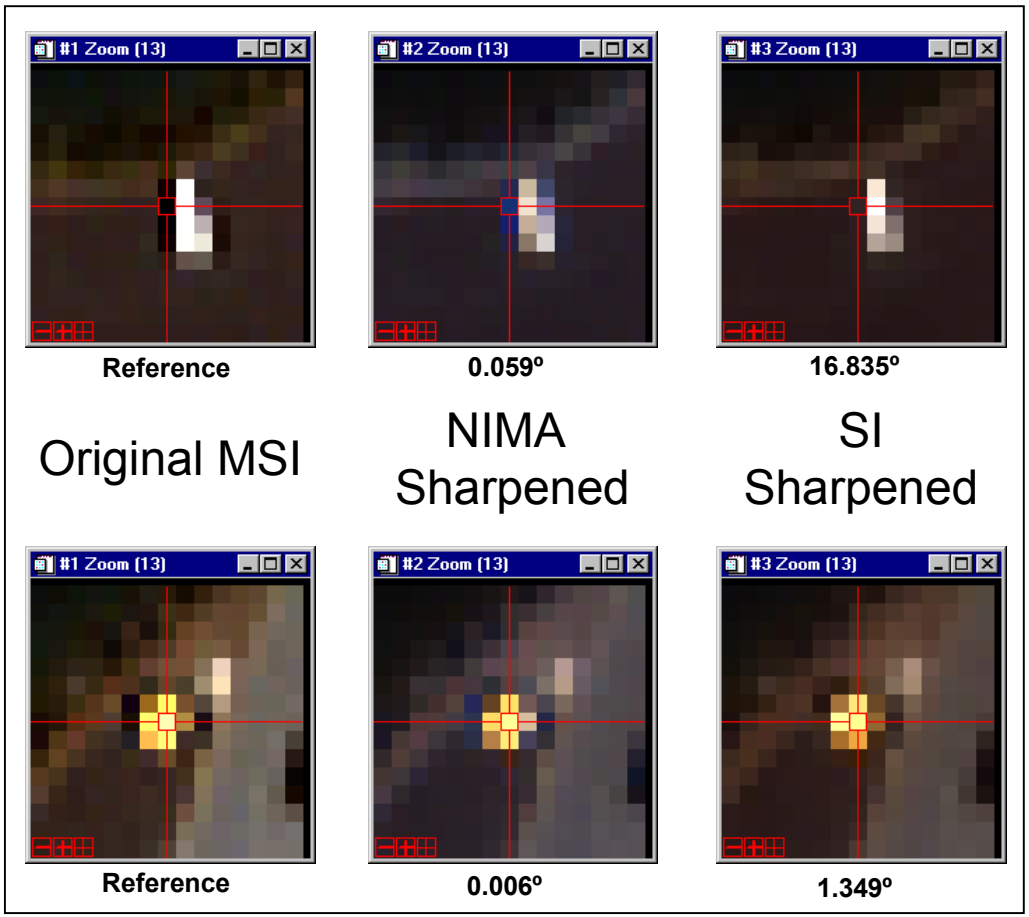
Localized Pixel Spectra

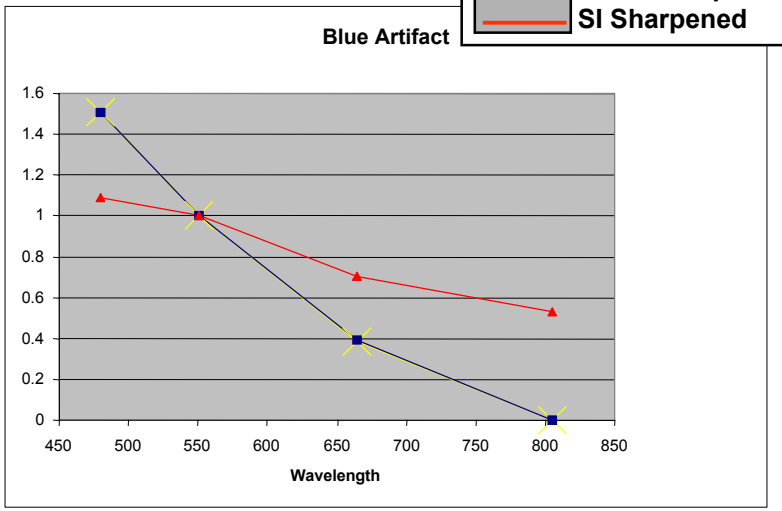


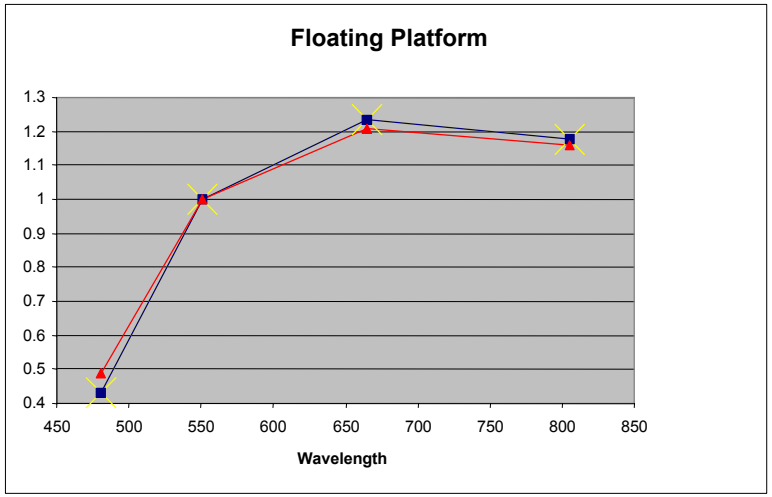




Localized Pixel Spectra
(Normalized)







Spectral Angles Calculated from Pixel Spectra

	NIMA	SI
Water	0.135	4.945
Vegetation	0.035	0.916
Barge (red)	0.036	0.555
Bridge	0.026	0.450
Artifact	0.059	16.835
Yellow	0.006	1.349
Average	***0.050***	***4.175***
STD	***0.045***	***6.426***

Spectral Angles (degrees)

- Individual spectra were extracted from single image pixels
- Spectral angles were computed for the pan-sharpened data using the pixel spectra from the original MSI as the reference
- Smaller spectral angles (>0.057 degrees) were observed for the NIMA products

Application

Normalized Difference Vegetation Index (NDVI)

- NDVIs computed for each pan-sharpened product and compared to the results from the original MSI

NIMA-Sharpened NDVI Difference Image

SI-Sharpened NDVI Difference Image

	NIMA	SI
MEAN Diff	0.0026	0.1240
RMS Error	1.53	76.50

NDVI Comparison with Original MSI

Summary

- Visual comparisons of both NIMA and SI pan-sharpened products to original Ikonos MSI data were made
  - SI pan-sharpened products agreed well with the original MSI
  - NIMA true color composite images appeared hazy
  - Visual differences in color appearance were less noticeable in the false color composite for both NIMA and SI pan-sharpened products
- Global comparison metrics were calculated for NIMA and SI pan-sharpened data
  - Best agreement was observed in the green and red data for each pan-sharpened product
- Correcting for bias and gain did not improve the visual appearance of the NIMA sharpened products
- Spectral angles were computed using the the original MSI data as the reference
  - Good spectral similarity to the original Ikonos MSI data was observed with NIMA pan-sharpened data
- NDVIs of both NIMA and SI pan-sharpened data were compared to NDVIs of original Ikonos MSI data
  - NIMA products agreed well with those of the original MSI data
  - SI NDVI results were inconsistent with the results from the original MSI data

Conclusions

- Color appearance of SI pan-sharpened products are more similar to the original MSI products than the NIMA pan-sharpened products
  - Results from the CCAP evaluation will give relative utility for visual interpretation in terms of NIIRS
- Using SI's products for applications using machine-based algorithms requiring spectral and/or radiometric fidelity is not suggested based on SI claims and the observed results
- SHARP does not perform optimally with Ikonos data due to the relative placement and shape of the Ikonos spectral response functions
- NIMA sharpened products demonstrate spectral similarity to the original MSI products and show utility in applications using machine-based algorithms that rely on spectral angle separations
- NIMA products demonstrate utility in applications where band ratios are used such as NDVI

Next Steps

- Current version of the SHARP algorithm is optimized for LANDSAT 5 data
- SHARP is being modified to incorporate mixing coefficients to improve the robustness of implementing the algorithm with imagery data from other systems
- SHARP revisions should improve the radiometric and spectral quality of NIMA pan-sharpened products produced with Ikonos data

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